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Possible Herd Immunity in the Elderly Following the Vaccination of School Children with Live, Attenuated Trivalent Influenza Vaccine: A Person-Level Analysis

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Abstract

Models predict that immunizing as few as 20% of school children, important transmitters of influenza, will reduce influenza-related illness in the elderly. We evaluated the potential herd immunity during three influenza seasons, 2005-2006, 2006-2007 and 2007-2008, which followed the immunization of ≥ 40% of school children in Knox County (KC), TN, with live, attenuated influenza vaccine. Individual-level demographic, health status and health service utilization information about KC residents ≥ 65 years and those residing in the 8 surrounding counties was obtained from the United States Medicare Program's administrative data. Influenza seasons were identified based on virus isolation. Pneumonia and influenza (P&I) hospitalization rates per 1,000 were compared between the elderly residing in the two areas for the three influenza seasons, and the 3 prior seasons. Differences-in-difference multivariate analysis allowed us to estimate the effect of the school-based immunization program on P&I hospitalization rates simultaneously adjusting for other important individual-level covariates. The age-adjusted rates among the KC residents were significantly lower, 4.62 and 6.02 versus 6.54 and 7.58 than in the residents of the comparison counties during the first two intervention seasons, p = 0.001 and 0.037, respectively, but not in the third. However, after adjusting for the traditionally lower rates of P&I hospitalization in the comparison counties, as well as for the other covariates, we were not able to demonstrate a statistically significant effect of the vaccination program in reducing the rates in either group of the elderly. The impact of the covariates was as expected. Those associated with increased P&I hospitalization rates were increasing age, lower income, poorer health status, prior hospitalization (particularly for P&I), and high prior use of physician services. Influenza immunization of an elderly person reduced his/her probability of being hospitalized for P&I. In conclusion, Immunization of ≥ 40% of school children did not result in a reduction of P&I hospitalization rates among the elderly. We believe that the failure to show an impact was likely due to the high level of immunization among the elderly (> 60%). Administration of influenza vaccine to children as a way to protect the elderly in situations where vaccine supplies are limited or the elderly are not accustomed to receiving influenza vaccine may still be appropriate.

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1. Introduction

School-aged children are among the first to become ill with influenza and are efficient transmitters of the disease. It has been hypothesized that immunizing children against influenza could protect communities against influenza by circulation of influenza viruses. Immunization of school children reduced both P&I and all-cause mortality among the elderly in Japan over a period of decades when the elderly were not routinely immunized. Mortality rose sharply when the national immunization program was discontinued in the 1990's [1]. A demonstration project in Michigan in 1968 found that the influenza attack rate in a community where more than 85% of school children were vaccinated was one-third the rate in a comparison community [2]. A study in Russia found that influenza rates in the unvaccinated elderly were reduced in communities where school children had been immunized prior to the 2001-2002 influenza season [3]. Recently, a cluster randomized trial of influenza vaccination of children in rural, communal religious communities in Canada demonstrated decreased influenza among unvaccinated members of these communities by 61% [4].

Annual immunization of school-aged children has recently been recommended in the United States [5]. This was for the direct benefit to the immunized child which has been demonstrated in several studies. Immunization of children enrolled in day-care centers [6] and schools [7-9] has been found to reduce illness, absenteeism, medical care and OTC medication use in the families of both immunized and unimmunized students. Modeling has suggested that vaccinating school children could reduce the spread of pandemic influenza with as low a coverage rate as 20% [10].

In the autumn of 2005, 2006, and 2007, 47%, 46% and 40% of children attending public schools in Knox County, Tennessee (TN), U.S.A. were immunized with live, attenuated trivalent influenza vaccine (LAIV). The goal of this study was to see if protection of the elderly residents of Knox County against influenza-related disease could be demonstrated. Specifically, we compared the rates of hospitalization for pneumonia and influenza (P&I) among the elderly (66+ years of age) residents of Knox County with the rates among the elderly residents living in the 8 counties surrounding Knox County during the influenza seasons for the 3 years the school children were vaccinated, as well as for the preceding 3 influenza seasons (2002-2003, 2003-2004 and 2004-2005). No school-based immunization activities were conducted in the 8 surrounding counties.

2. Methods

2.1. Data sources and study information

Influenza seasons were defined using influenza virus isolation information obtained from TN State Department of Health [11] for the years 2002 through 2008 for the entire state of TN. The influenza season was considered to begin at the start of the week when the cumulative percentage of influenza isolates during each fall/winter reached 2.5%. The season was deemed to end at the end of the week when the cumulative percentage reached 97.5% [12].

United States Medicare Program annual enrollment data files (Denominator Files) for 2002 through 2008 were used to identify beneficiaries who received health care on a fee-for-service basis. After excluding those with End Stage Renal Disease, cohorts of beneficiaries 65+ year of age were created for Knox County residents and for the 8 comparison counties. Because one year of Medicare experience and claims were used to determine the health status of each individual and the use of health services in the Medicare Program in the year prior each influenza season, the analysis was of persons 66+ years of age.

Hospitalizations for P&I for each influenza season were identified in the annual Medicare Provider Analysis and Review (MedPAR) files for the years 2002 through 2008. The MedPAR file is a well known and frequently used Medicare administrative data file that contains one record for each hospitalization for all Medicare fee-for-service beneficiaries. Hospitalizations for P&I were identified using ICD-9-CM codes 481-487.X. Only one hospitalization per person (the first) was counted during each influenza season. Based on our prior experience, only P&I diagnoses in the primary diagnosis position were counted. This is largely based on the assumption that the effect of childhood vaccination-induced reduction of circulation of the influenza virus should reduce rates of community-acquired P&I more than hospital acquired infections. Also, the pattern of P&I diagnoses in the primary position and in all 10 available positions in the MedPAR file follows a very similar pattern with the number of cases with P&I in the primary position being about 60-65% of all P&I hospitalizations.

The Medicare annual Denominator Files for 2002 through 2008 were the source of information regarding age, gender, race, place of residence (available down to the postal zip code level), and participation in the state Medicaid program (a program for people of low income).

The annual MedPAR and Carrier files (the latter contains information on physician visits and services provided by other non-institutional Medicare providers) for 2002 through 2008 were used to determine the health status of each beneficiary as measured by the Charlson co-morbidity index (0, 1-2, 3+) [13], receipt of the influenza vaccine for that season, any hospitalization in the "prior year" (The prior year was defined as the 365 days prior to the date of P&I hospitalization during the influenza season or the mid-point of the influenza season for those who were not hospitalized for P&I.), any hospitalization for P&I in the prior year, and number of physician office visits in the prior year. Influenza vaccination status was determined from Carrier file claims for influenza vaccine or influenza vaccine administration received between September 1 and December 31. All of these variables were used in the multivariate analyses described below.

2.2 Data analysis

Crude and age-adjusted rates (per 1,000) of P&I hospitalizations for each influenza season were compared between the elderly residents of Knox County and the 8 surrounding counties. The standard population used in the age-adjustment was the combined elderly population of Knox and the 8 surrounding counties in 2005-2006. These comparisons were first carried out for the total elderly cohorts. In addition, because we hypothesized that any herd immunity effect might be greater among persons who did not receive influenza vaccination, all analyses were carried out for those members of each cohort who did not receive influenza vaccine during the 3-month period prior to each influenza season, also. The z test was used to evaluate the differences in rates, and p-values assigned based on the z score. A p-value of < 0.05 was judged as significant. The effectiveness of the school-based immunization program can be estimated using the rates of P&I hospitalization: program effectiveness = 1 – relative risk of P&I hospitalization; or 1- (rate of P&I $\text{hospitalization}_{\text{intervention county}}$ / rate of P&I $\text{hospitalization}_{\text{comparison counties}}$.

Because this was an observational study, multivariate logistic models were created and run to control of known and unknown bias. Initially, models for each individual influenza season were run separately to assess the effect of the county of residence, adjusting for potential confounding due to differences in the distribution of known variables in the intervention and comparison populations. Then, difference-in-differences logistic models were created and run using all influenza seasons simultaneously to assess the impact of the school vaccination effort in Knox County. Application of this method to our study is appropriate because one of the cohorts (Knox County residents) was exposed to the school-based program from 2005-2006 through 2007-2008 but not from 2002-2003 through 2004-2005. The residents of the 8 surrounding counties (comparison group) were not exposed to the intervention during either period. In the analysis, the average change in P&I hospitalization rates between the pre-intervention and intervention time periods in the comparison group was subtracted from the average change in treatment group. This removes biases in second period comparisons between the treatment and comparison group that could be the result from permanent differences between those groups, as well as biases from comparisons over time in the treatment group that could be the result of secular trends [14]. The following logistic regression equation incorporating the covariates described earlier was used:

Logistic (P(P&I Hosp = 1)) = $\alpha + \beta_1$Knox + β_2Knox * Post(2005/06, 2006/07, 2007/08) + β_3Flu Season Year + β_4X + error

where X = covariates (age-group, gender, race, Medicaid program participation, median income of zip code, Charlson index, prior hospitalization, prior P&I hospitalization and prior physician office visits).The interaction term β_2 measures the differential impact of the school-based immunization program on the odds of P&I hospitalization for the Knox county residents relative to the 8 surrounding counties.

This study was conducted with the approval of the University of Minnesota Human Research Protection Program IRB Code Number 0907M69522.

3. Results

The influenza seasons for the study period are shown in Table 1. They varied in duration from 9 to 16 weeks.

Table 1. Periods of Influenza Virus Isolation (Influenza Season) in Tennessee, 2002-2003 through 2007-2008.

Influenza season	Time period "CDC Weeks"	Number of weeks
2002-03	Weeks 51 - 11	13
2003-04	Weeks 45 - 1	9
2004-05	Weeks 51 - 11	13
2005-06	Weeks 51 - 11	13
2006-07	Weeks 49 - 13	12
2007-08	Weeks 1 - 16	16

The distributions of the characteristics of the study cohorts in the intervention county and the comparison county were statistically significantly different for the majority of the variables studied: age-group, gender, race, Medicaid program participation, median household income of the zip code of residence, hospitalization in the prior year, hospitalization for P&I in the prior year, and the number of physician office visits in the prior year. These results were consist in all years. Only the distribution of the Charlson co-morbidity index and the rates of prior hospitalization were similar in the two populations. Table 2 presents the information for 2005-2006, as an example.

Table 2. Characteristics of Medicare beneficiaries residing in Knox County and in the 8 surrounding counties. Influenza season 2005-2006, presented as an example.

		8 Surrounding Counties		Knox County		
		N	%	N	%	P value
Total elderly population		50,009	58.9	34,843	41.1	
Age-group (years)	66-74	25,440	44.8	15,936	45.7	<.0001
	75-84	18,474	40.0	14,090	40.4	
	85+	6,095	15.2	4,817	13.8	
Gender	Male	21,092	42.2	13,659	39.2	<.0001
	Female	28,917	57.8	21,184	60.8	
Race	White	48,960	97.9	32,469	93.2	<.0001
	Black	802	1.6	2,044	5.9	
	Other	247	0.5	330	1.0	
In Medicaid Program	Yes	7,517	15.0	4,530	13.0	<.0001
	No	42,492	85.0	30,313	87.0	
Median income	< $35,600	29,536	59.1	13,283	38.1	<.0001
	$35,600 - $45,400	19,097	38.2	13,468	38.7	
	>$45,400	1,376	2.8	8,092	23.2	
Charlson Score	0	20,463	40.9	14,304	41.1	0.3651
	1-2	18,851	37.7	13,230	38.0	
	3+	10,695	21.4	7,309	20.9	
Influenza vaccination	Yes	29,646	59.3	21,446	61.6	<.0001
	No	20,363	40.7	13,397	38.5	
Prior hospitalization	Yes	9,477	19	6,468	18.6	0.0703
	No	40,532	81.1	28,375	81.4	
Prior P&I hospitalization	Yes	1,352	2.7	850	2.4	0.0173
	No	48,657	97.3	33,993	97.6	
Number of physician visits in prior year	<5	21,802	43.6	14,950	42.9	0.0149
	5-9	17,797	35.6	12,449	35.7	
	10-14	5,796	11.6	4,017	11.5	
	15+	4,614	9.2	3,427	9.8	

The crude and age-adjusted rates of P&I hospitalization among the total and the unvaccinated elderly Knox County residents and the 8 comparison counties residents are presented in Figures 1 and 2, respectively, and Table 3. Among the total population, the age-adjusted rates of P&I hospitalization were significantly lower among Knox County elderly residents in the 2005-2006 and 2006-2007 influenza seasons than among the elderly residents of the 8 surrounding counties, p = 0.0012 and 0.0370, respectively. These differences of 26.4% and 16.7%, respectively, provide an initial estimate of the vaccine program effectiveness in these years. The difference of 13.9% in 2007-2008 did not achieve statistical significance (p = 0.917). In one of the pre-intervention seasons (2002-2003), the rate was statistically significantly lower in Knox County residents, and it was close to being significantly different in another (2004-2005).

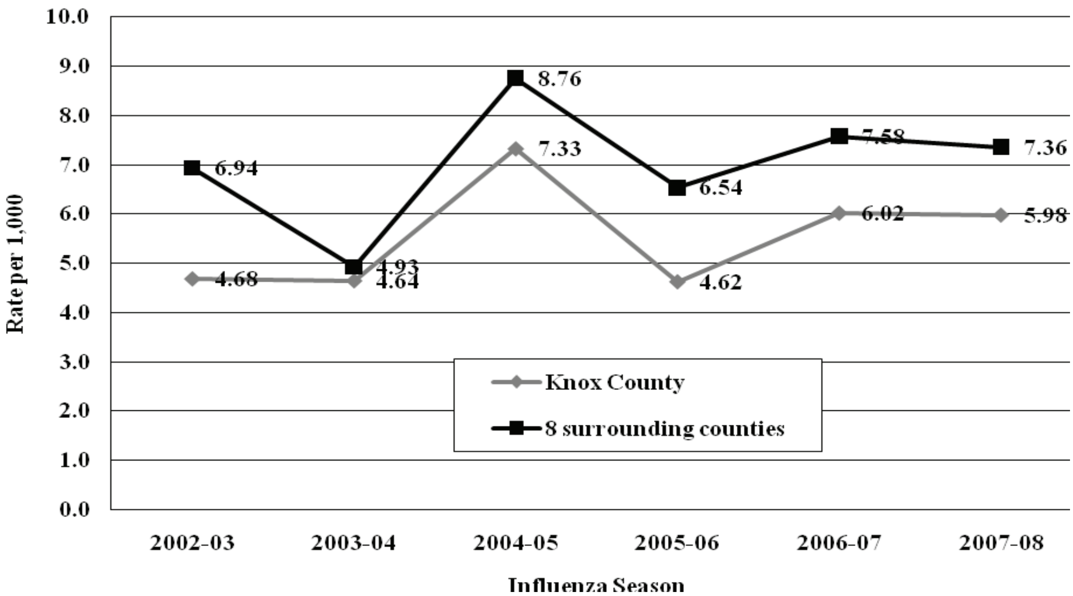


Figure 1. Age-adjusted P&I hospitalization rates per 1,000 elderly residents of Knox County and of the 8 surrounding counties, by influenza season.

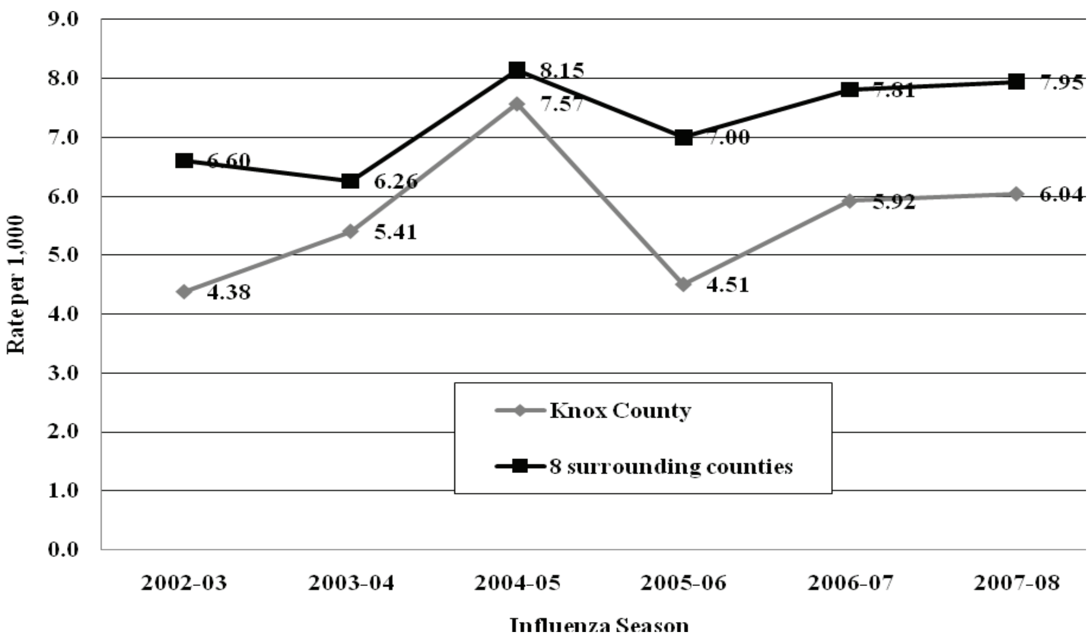


Figure 2. Age-adjusted P&I hospitalization rates per 1,000 unvaccinated elderly residents of Knox County and of the 8 surrounding counties, by influenza season.

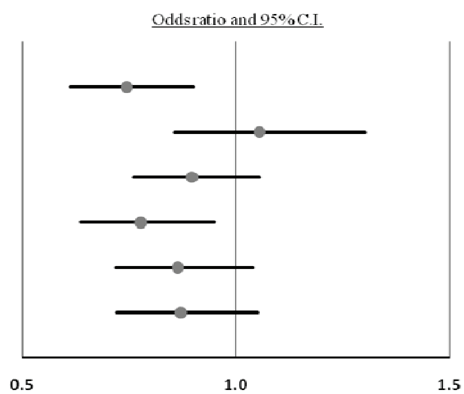
Table 3. Crude P&I Hospitalization Rates per 1,000 Knox County residents and the residents of the 8 surrounding counties and the percent differences between them for the total and unvaccinated elderly populations, by influenza season.

	Total elderly population				Unvaccinated elderly population			
Influenza season	Knox county	8 other counties	Difference (1-($Rate_{KC}$/ $Rate_{8C}$))	p value	Knox county	8 other counties	Difference (1-($Rate_{KC}$/ $Rate_{8C}$))	p value
2002-03	4.71	6.73	46.1%	0.0001	4.35	6.20	29.8%	0.0144
2003-04	4.66	4.80	2.8%	0.7719	5.41	5.97	9.3%	0.4977
2004-05	7.45	8.53	12.6%	0.0818	7.61	7.72	14.4%	0.8793
2005-06	4.74	6.44	26.4%	0.0012	4.55	6.68	31.8%	0.0121
2006-07	6.26	7.51	16.7%	0.0370	5.91	7.39	20.0%	0.1054
2007-08	6.27	7.28	13.9%	0.0917	6.18	7.48	17.4%	0.1295

The multivariate model results for the total population of elderly (Table 4) were generally similar to the results presented immediately above. In all the intervention seasons the odds ratio for the variable "Knox County resident" had values < 1.00. However, in only one, 2005-2006, did the upper limit of the 95% confidence limit not include 1.00 indicating that living in Knox County significantly reduced the risk of being hospitalized for P&I. Similarly, in one of the three non-intervention seasons, 2002-2003 living in Knox County reduced the risk of hospitalization for P&I.

Table 4. Multivariate model results (Odds ratio and 95% C.I.) of the effect of living in Knox County compared with the 8 surrounding counties on P&I hospitalization rate among the total elderly population.

Influenza season	Odds Ratio	Lower limit	Upper limit
2002-03	0.744	0.613	0.902
2003-04	1.055	0.856	1.301
2004-05	0.896	0.760	1.055
2005-06	0.777	0.636	0.950
2006-07	0.863	0.717	1.038
2007-08	0.870	0.720	1.051

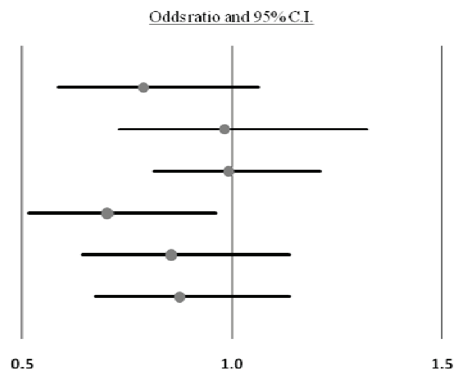


Among the unvaccinated elderly population, the age-adjusted rates of P&I hospitalization appeared to be lower among Knox County elderly residents in the three intervention seasons (Figure 2). However, in only one, 2005-2006, did it reach statistical significance: difference = 31.8%, p = 0.0121. In one of the pre-intervention seasons, 2002-2003, the rate was statistically significantly lower in Knox County residents, also: difference = 29.8%, p = 0.0144.

The multivariate model results for the unvaccinated population of elderly (Table 5) showed no effect for being a Knox County resident in the pre-intervention season 2002-2003. However, the results for 2005-2006 were consistent with the bivariate results as well as the findings for the total elderly population (Tabel 4). Also to be noted is that the odds ratios in each of the three intervention seasons were approximately the same for total and the unvaccinated population; however the confidence bands were larger for the unvaccinated population due to the fact that approximately 60% of the elderly were vaccinated each year (Table 2) which reduced the sample size for these calculations.

Table 5. Multivariate model results (Odds ratio and 95% C.I.) of the effect of living in Knox County compared with the 8 surrounding counties on P&I hospitalization rate among the unvaccinated elderly population.

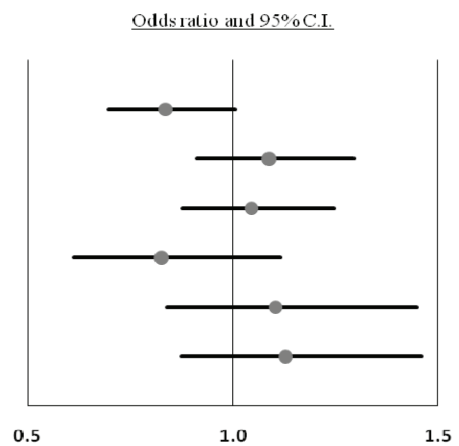
Influenza season	Odds Ratio	Lower limit	Upper limit
2002-03	0.789	0.586	1.062
2003-04	0.982	0.730	1.321
2004-05	0.992	0.815	1.209
2005-06	0.703	0.515	0.961
2006-07	0.855	0.644	1.136
2007-08	0.875	0.675	1.135



In the difference-in-differences model results which allow us to adjust for the habitually lower rate of P&I hospitalizations among the elderly residents of the 8 surrounding counties, as well as for secular changes that might affect all of the counties in the study, no effect was seen for the school-based intervention in Knox County (Table 6). In the 2005-2006 influenza season the odds ratio for the interaction term indicating an effect of the school-based immunization program was < 1 for both the total and the unvaccinated cohorts, but for both groups the upper limit of the 95% confidence interval was > 1. For the other two intervention years, the odds ratios were > 1 for both the total and the unvaccinated cohorts, and the 95% confidence intervals included 1. Thus, there was no impact of the school-based immunization program on the P&I hospitalization rates.

Table 6. Difference-in-differences model results (Odds ratio and 95% C.I.) of the effect of the school-based vaccination program on P&I hospitalization among the total population and the unvaccinated elderly population of Knox County.

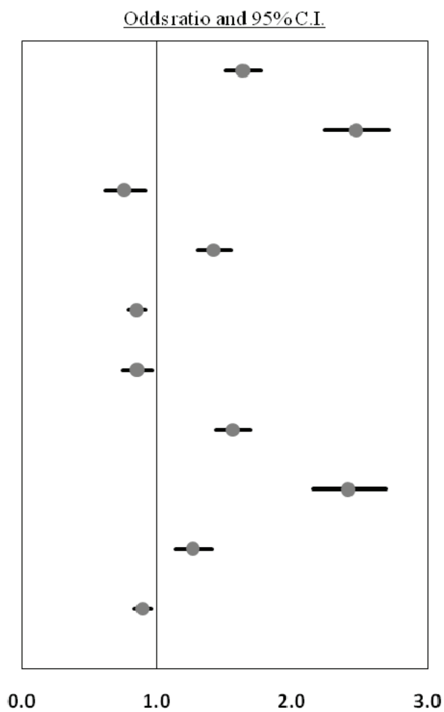
Influenza season	Odds Ratio	Lower limit	Upper limit
Total			
2005-06	0.836	0.698	1.007
2006-07	1.088	0.914	1.295
2007-08	1.046	0.877	1.247
Unvaccinated			
2005-06	0.827	0.613	1.116
2006-07	1.104	0.840	1.450
2007-08	1.129	0.873	1.459

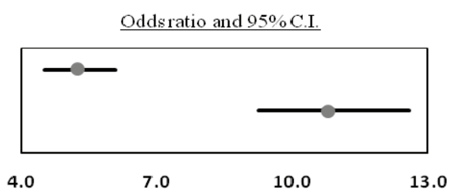


The information presented in Table 7, the odds ratios and 95% confidence limits for the covariates included in the difference-in-differences model, supports the inclusion of these variables in the model, as well as the appropriateness of the model. The risk of being hospitalized increased with increasing age-group. It was higher for those in a Medicaid program, as well as for those with increasing co-morbidity scores, or those who had a prior hospitalization, a prior P&I hospitalizations or visited a physician ≥ 15 times in the prior year. Reduced probabilities of being hospitalized for P&I were associated with higher income for the zip code of residence and vaccination against influenza in the period before the influenza season. All of these findings are consistent with expectations.

Table 7. Difference-in-differences model results (Odds ratio and 95% C.I.) of the effect of covariates on probability of P&I hospitalization among elderly residents of Knox County and the 8 surrounding counties.

Covariate	Odds Ratio	Lower limit	Upper limit
Age 75-84 vs. 66-74 (ref.)	1.631	1.501	1.772
Age 85+ vs. 66-74 (ref.)	2.469	2.241	2.720
Race Black vs. White (ref.)	0.749	0.614	0.914
In Medicaid Program vs. not (ref.)	1.416	1.300	1.543
Middle income vs. low (ref)	0.845	0.782	0.912
High income vs. low (ref.)	0.847	0.738	0.963
Hospitalized in prior year vs. not (ref.)	1.555	1.432	1.688
P&I hospitalization in prior year vs. not (ref.)	2.409	2.153	2.697
Number of physician visits : 15+ vs. < 5 (ref.)	1.261	1.132	1.404
Influenza vaccination vs. none (ref.)	0.890	0.827	0.958
Charlson Score 1-2 vs. 0 (ref.)	5.236	4.506	6.085
3+ vs. 0 (ref.)	10.783	9.246	12.576





4. Discussion

Rates of P&I hospitalization among elderly residents of a county in which ≥ 40% of school children were immunized with LAIV were significantly lower in two of the three intervention years studied. The rates in the unimmunized elderly were lower in the first of these years, also. However, after adjusting for the historic lower rates of P&I hospitalization in the comparison counties, as well as for other important covariates affecting P&I hospitalization, we were not able to demonstrate a statistically significant effect of the vaccination program in reducing the rates in either group of the elderly.

Our results are inconsistent with the previously published studies cited in the Introduction section of this paper [1-4]. In each of these studies, a reduction in influenza-related mortality, morbidity, or health service use was reported among the elderly and/or the general adult population following the administration of influenza vaccine to children in the community. However, there may have been important differences in the study setting that could explain the inconsistent findings. We believe the primary difference is the low to non-existent rate of vaccination of the elderly or adult population included in the other studies. In Japan during the period of heightened immunization of children, 80% of children 7-15 year-old children were vaccinated annually. However, very little influenza vaccine was administered to the elderly or others at high risk [1]. During the Hong Kong influenza outbreak of 1968, 86% of school children were immunized against the virus in Tecumseh, Michigan. Only children were given the vaccine. None of the vaccine which contained a Hong Kong variant of Type A influenza was given to adults and the commercially available vaccine for that season available to adults in the community did not protect against Hong Kong influenza [2]. In the study in which 65% of school children in a community near Moscow, < 1% of the elderly were vaccinated in the intervention and the comparison communities [3]. In the religious communities of Western Canada where 83% of children 36 months to 15 years of age were vaccinated against influenza in 2008, only 12% of the non-target age-group received influenza vaccine [4].

Our results are more consistent with other recent results from studies in the United States. Talbot et al., also studied the impact of the Knox County school-based immunization program in the 2006-2007 influenza season [15]. They reported similar rates of real time reverse transcriptase-polymerase chain reaction (RT-PCR) detected cases of influenza among persons 65+ years of age, admitted to hospital with acute respiratory symptoms or non-localized fever living in Knox County compared with persons living in Davidson County, TN, a somewhat similar county to Knox about 180 miles away. Lower rates of influenza-related hospitalizations were reported in the Knox County residents 50-64 years of age than among the Davidson County residents. King et al., [9] working in Maryland report significantly lower rates of medically attended acute respiratory infections (MAARI) emergency room visits associated with a 20% increase in county-level immunization rates of school-age children among adults 19-49 years of age in the first two of the three influenza seasons they studies from 2005-2006 through 2007-2008. No effect was found among those 50+ years of age for this outcome. However, they do not present data for age sub-groups 50-64 and 65+ years. During the time of both of these studies, as well as ours, universal immunization of the adult United States population was still not recommended. Thus, the National Centers for Disease Control and Prevention's (CDC) National Health Interview Survey (NHIS) influenza immunization coverage rates for 2005, 2006 and 2007 were 10.7%, 15.5% and 17.8%, respectively for those 18-49 years of age; 23.0%, 33.1% and 36.2%, respectively, for those 50-64 years of age; and 59%, 64.1% and 66.8%, respectively, for those 65+ years of age [16-18]. We believe that the information from these two studies, as well as our current report, support the position that documentation of school-based immunization programs causing herd immunity in highly immunized elderly (65+) populations such as in the United States may not be possible. Herd immunity is more likely to be shown in other American adult populations with low levels of immunity (those 18-49 or 50-64 years), or in elderly populations to whom influenza vaccine is not provided.

Another difference between our work and some previously published publications, references 1-4, is that LAIV was administered in Knox County and inactivated influenza vaccine was used in these other studies. However, other studies cited earlier have shown the LAIV used during these seasons to be effective in reducing influenza-related morbidity or health service utilization in the children targeted for immunization [7-9]. Thus, we do not believe that LAIV can be considered a cause of the discrepancy. Further, LAIV has the same formulation as the inactivated vaccine prepared in the United States. One possible vaccine-related factor that could impact herd immunity is the antigenic similarity of the vaccine virus strains and the viruses that circulate during the influenza season. In their article, King et al., presented a "weighted mean match" between the three CDC recommended influenza vaccine virus strains for 2005-2006 through 2007-2008 and the circulating virus strains [9]. For all seasons the proportion that matched was 0.49. It was quite good for each of the first two seasons, 0.67, but only 0.27 in the 2007-

2008 influenza season. This latter finding could have contributed to the lack of a herd immunity effect in the latter year in their study and ours.

The use of the difference-in differences model allowed us to take advantage of information for the time period prior to the implementation of the school-based immunization program. The history of consistently lower rates of P&I hospitalization in Knox County compared with the 8 surrounding counties has been recently reported for 2000-2005 [19]. As pointed out by the authors of the latter paper, the synchronous temporal patterns of influenza-related health service use among 5-17 year-olds (and presumably other age groups, as well) who live in Knox County and those who live in the 8 surrounding counties makes the latter an appropriate comparison population to assess the impact of the school-based immunization program. However, the rate ratios (8 surrounding counties/Knox County) they calculate and present of approximately 0.8 present for the pre-intervention years 2000-2005 need to be accounted for in the assessment of the impact of the program. The difference–in-differences model allowed us to accomplish this. The fact that the odds ratios for the covariates were consistent with what we would hypothesize or is known form the literature reinforces the selection of the model to analyze the data, and add credibility to the results.

In summary: (1) Immunization of $\geq$ 40% of school children is not consistently associated with reduced rates of P&I hospitalization among either the total elderly population or among the unvaccinated elderly population living in the same area, and (2) difference-in-differences results show no impact of the vaccination program in any intervention year.

We conclude that immunization of school children at this level in a community in which the elderly are highly immunized (> 60%) does not reduce P&I hospitalization rates among the elderly. However, further studies in other locations could be warranted if (1) higher levels of immunization were achieved among the school children, and (2) there were lower levels of immunization among the elderly. In situations such as the appearance of the novel H1N1 influenza strain in 2009 where there is insufficient vaccine to immunize an entire population and the there is no immunologic memory in the community, it may be prudent for children to be the highest priority group to be vaccinated in the general population. Although we do not provide information from this study for this position, the information from other work cited is supportive [1-4].

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